EARTH'S DYNAMIC SYSTEMS

17 Plate Tectonics

Before Plate Tectonics: Theory of Continental Drift

- Predecessor to modern plate tectonics
- Shape and “fit” of the continents was the initial evidence
  - Snider-Pelligrini (1858)
  - Taylor (1908)
  - Wegner (1915)

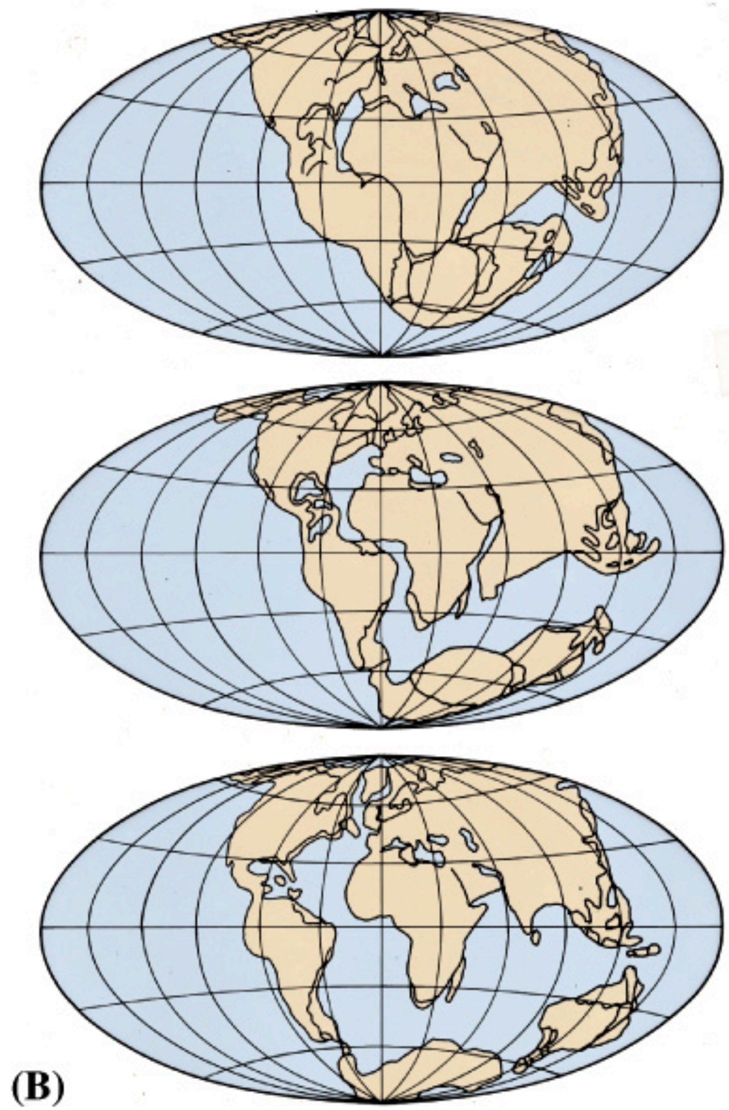


Fig. 17.1b. Continental drift maps by Wegner (1915)

Continental Drift

- Alfred Wegener (1915)
  - Proposed that all of the continents were once part of a large supercontinent - Pangaea
  - Based on:
    - Similarities in shorelines- jigsaw puzzle fit
    - Evidence: fossils, rock types & structures, glaciation from S. Am, Africa, Asia, Australia and India

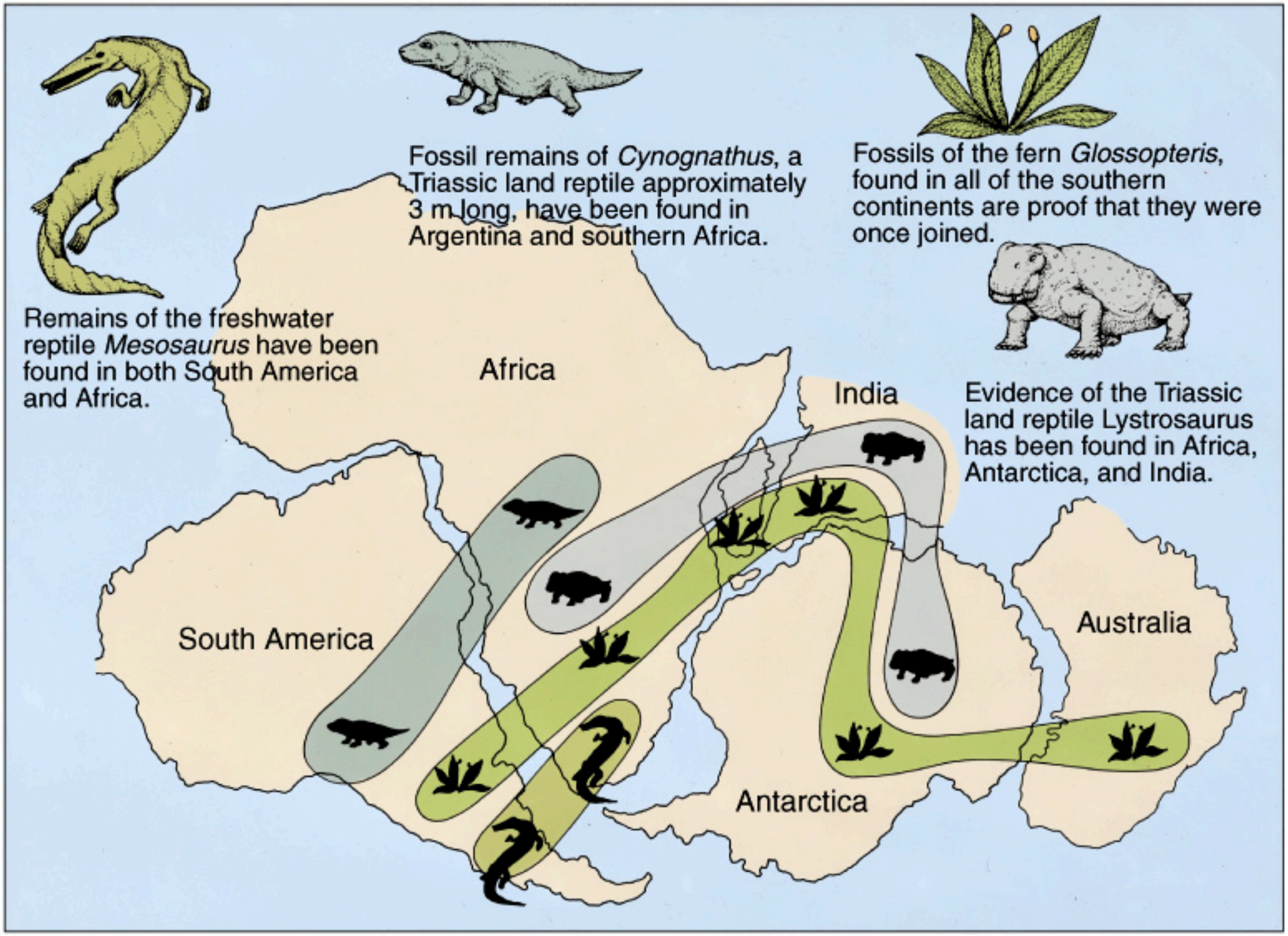
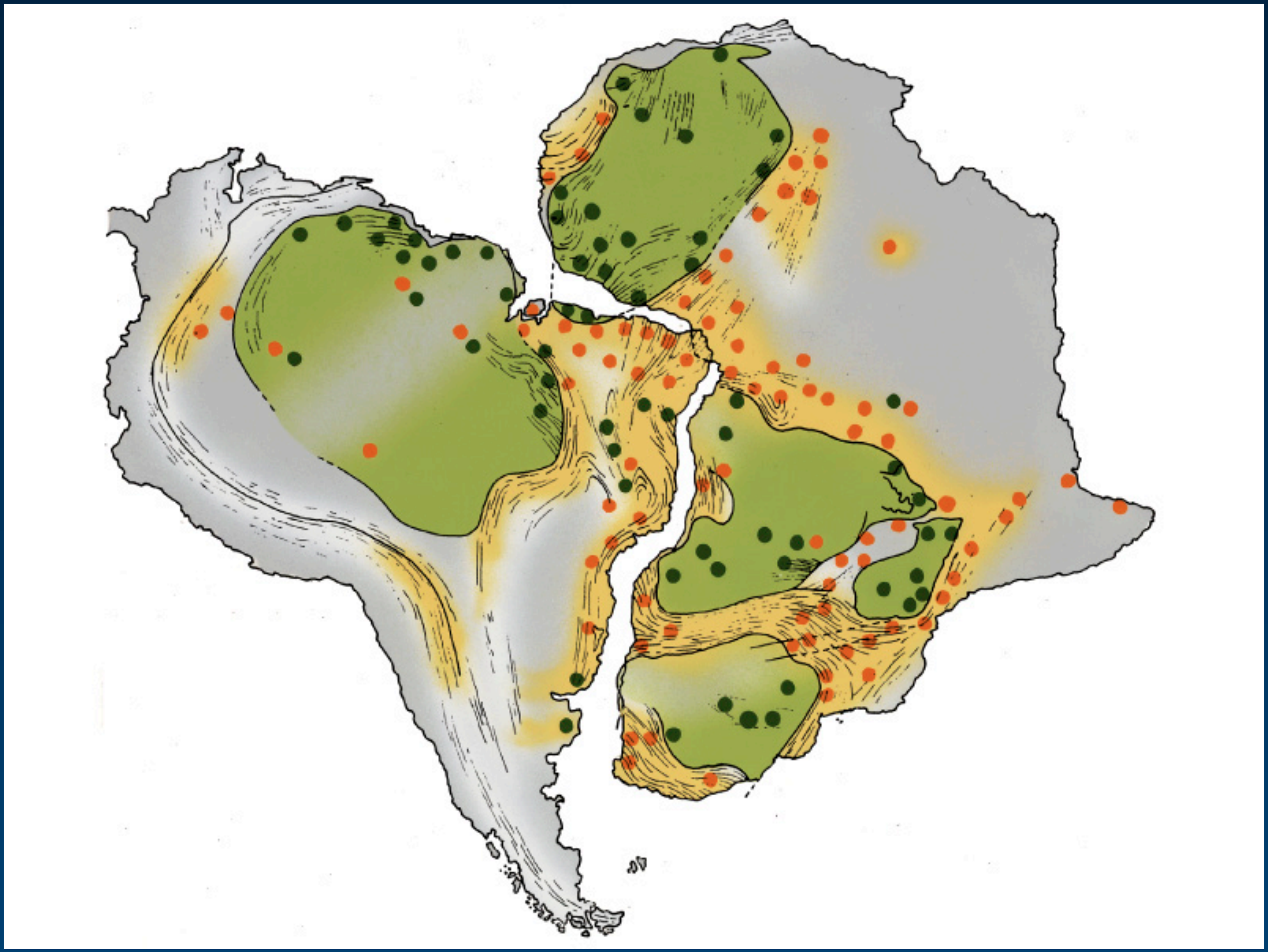


Fig. 17.2. Paleontological (fossil) evidence



Green dots: rks > 2 byo, part of meta. & ign. rks of cont. shields
Orange dots: younger PreC rks; Structures (fold axis): dashed

Fig. 17.5 Reconstruction from glacial deposits

Development of Plate Tectonic Theory

- Original evidence for continental drift was from continental rocks BUT no good explanation for mechanism
- Technological advances in the 1950's and 1960's allowed investigation of the sea floor; pre-1950 ????? re ocean floor
- Geophysics & paleomagnetism provided new data

Geology of the Ocean Floor

- From echo sounding: Topography of the ocean basins
  - Basins are divided by a large ridge system
  - Ridge system is continuous around the entire globe – 65,000 km, 1500 km wide
  - Central rift valley within the ridge

Geology of the Ocean Floor

- Physical properties
  - From drilling /dregding: 1)floor composed of basalt and 2)ocean floor younger in age than most continental rocks
  - From seismic studies: 1)Oceanic crust is thinner than continental and 2) No evidence of crustal deformation – folded mountains on ocean floor

Geology of the Ocean Floor

- Seafloor spreading proposed by Hess (1960)
  - Considered new data on ocean floor
  - Proposed mechanisms of:
    - Mantle convection
    - Rifting and volcanism along ridge system
    - Continents pushed along w/ spreading seafloor
    - Recycling of oceanic crust by subduction

Geology of the Ocean Floor

- Paleomagnetism
  - Fe rich rocks (basalt) are weakly magnetized by the Earth's magnetic field as minerals crystallize/cool from magma
  - Orientation of magnetic field is preserved- these Fe minerals become 'fossil' magnets

Geology of the Ocean Floor

- Magnetic reversals
  - Earth's magnetic field polarity has reversed through time
    - Normal polarity – $N_{magnetic} = N_{geographic}$
    - Reversed polarity - $N_{magnetic} = S_{geographic}$
    - At least 12 reversals in last 4 my
    - These 'fossil' magnets – Fe minerals in basalts will either show normal OR reversed polarity

Geology of the Ocean Floor

- Vine & Matthews (1963) tested Hess's sea floor spreading hypothesis using magnetism
  - Magnetic polarity reversals recorded in ocean floor basalt
    - Magma cools forming new crust
    - Polarity at time of cooling preserved
    - Old crust pushed aside

Geology of the Ocean Floor

- Magnetic polarity stripes in ocean crust parallel the midoceanic ridges
  - Symmetrical on either side of the ridge
  - Age of seafloor also known (from patterns established from dating cont. rks)
    - Increases away from ridge *******
    - Rates of plate motion may be calculated****

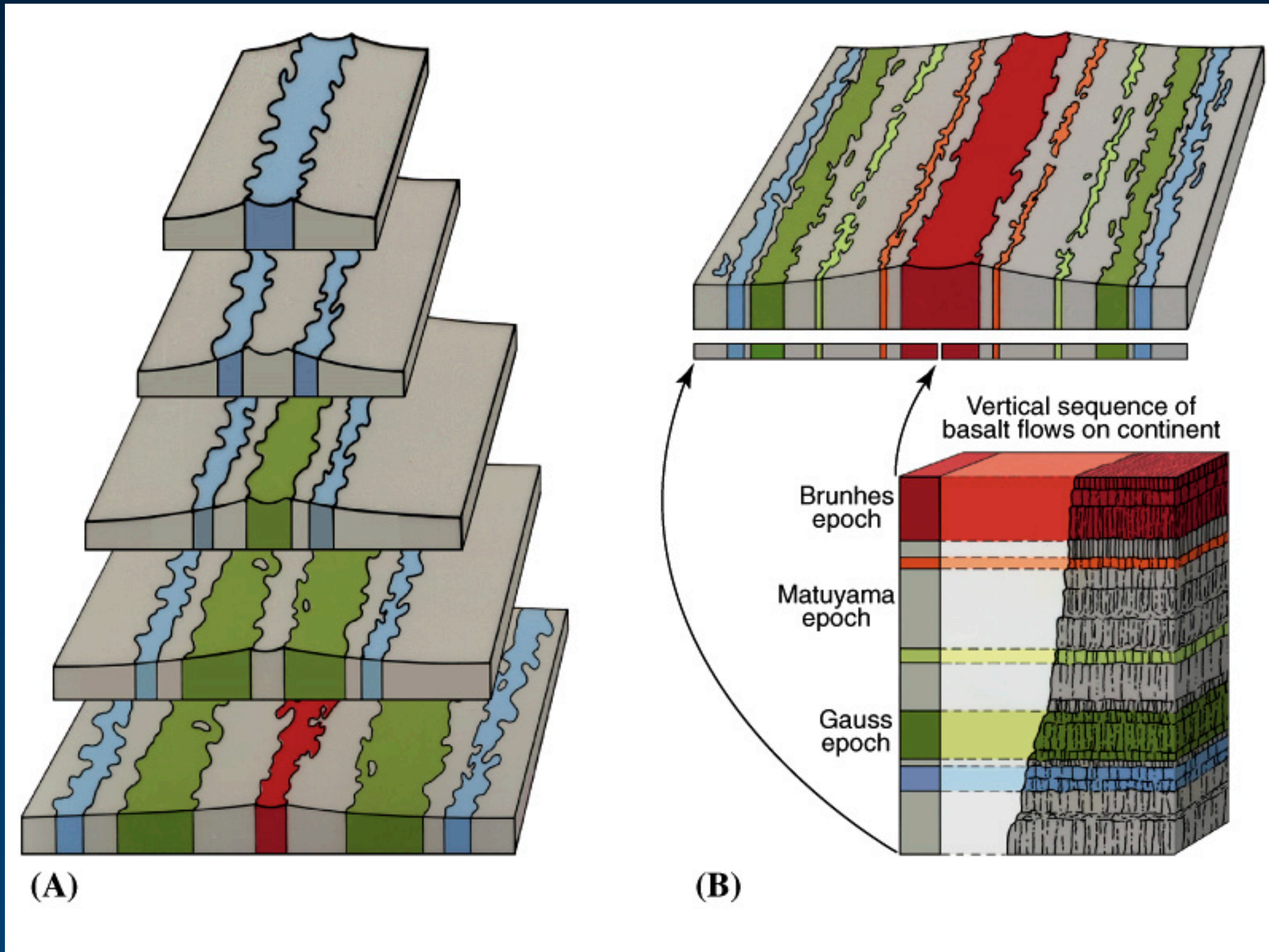


Fig. 17.10. Patterns of magnetic reversals

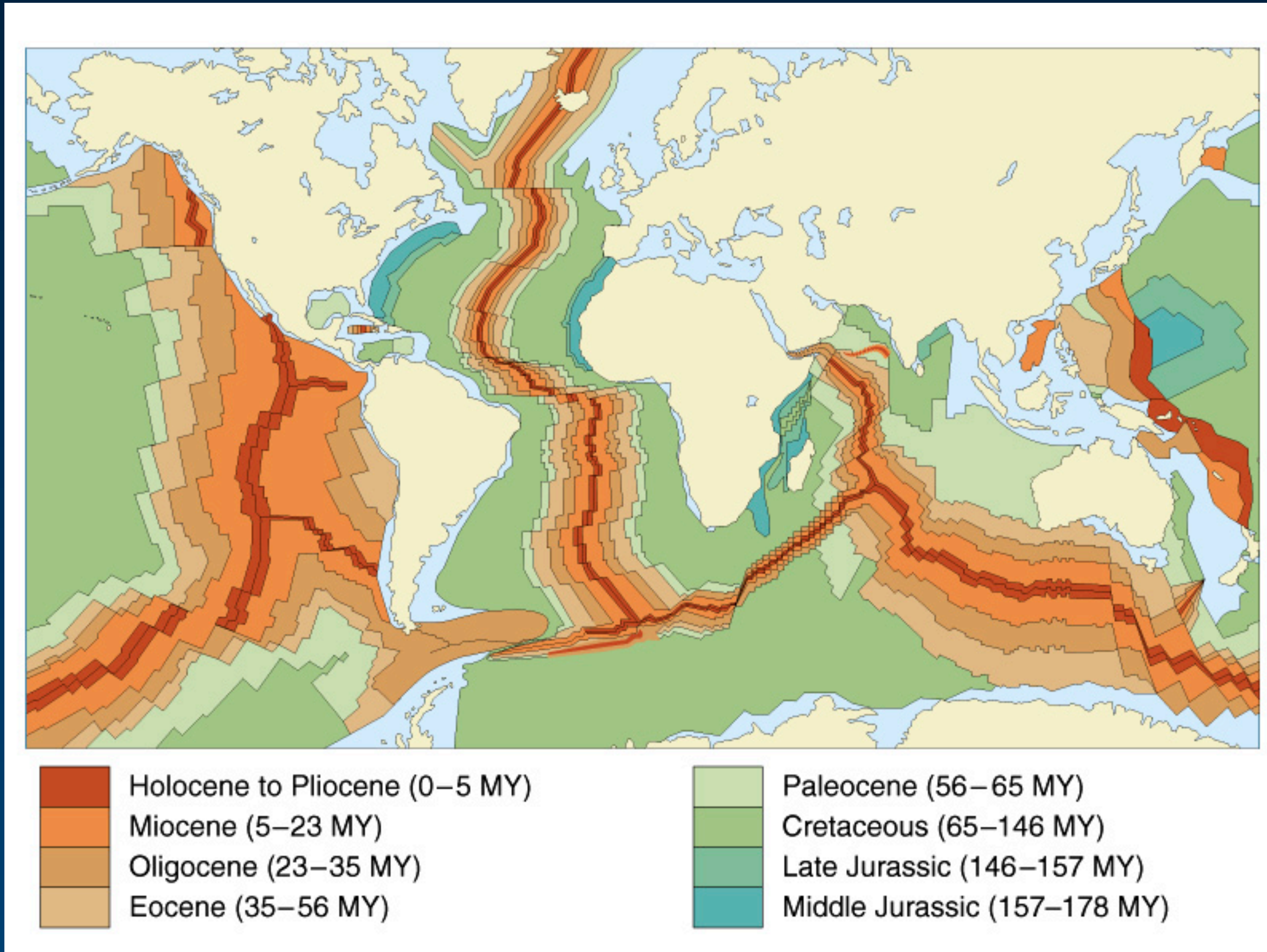


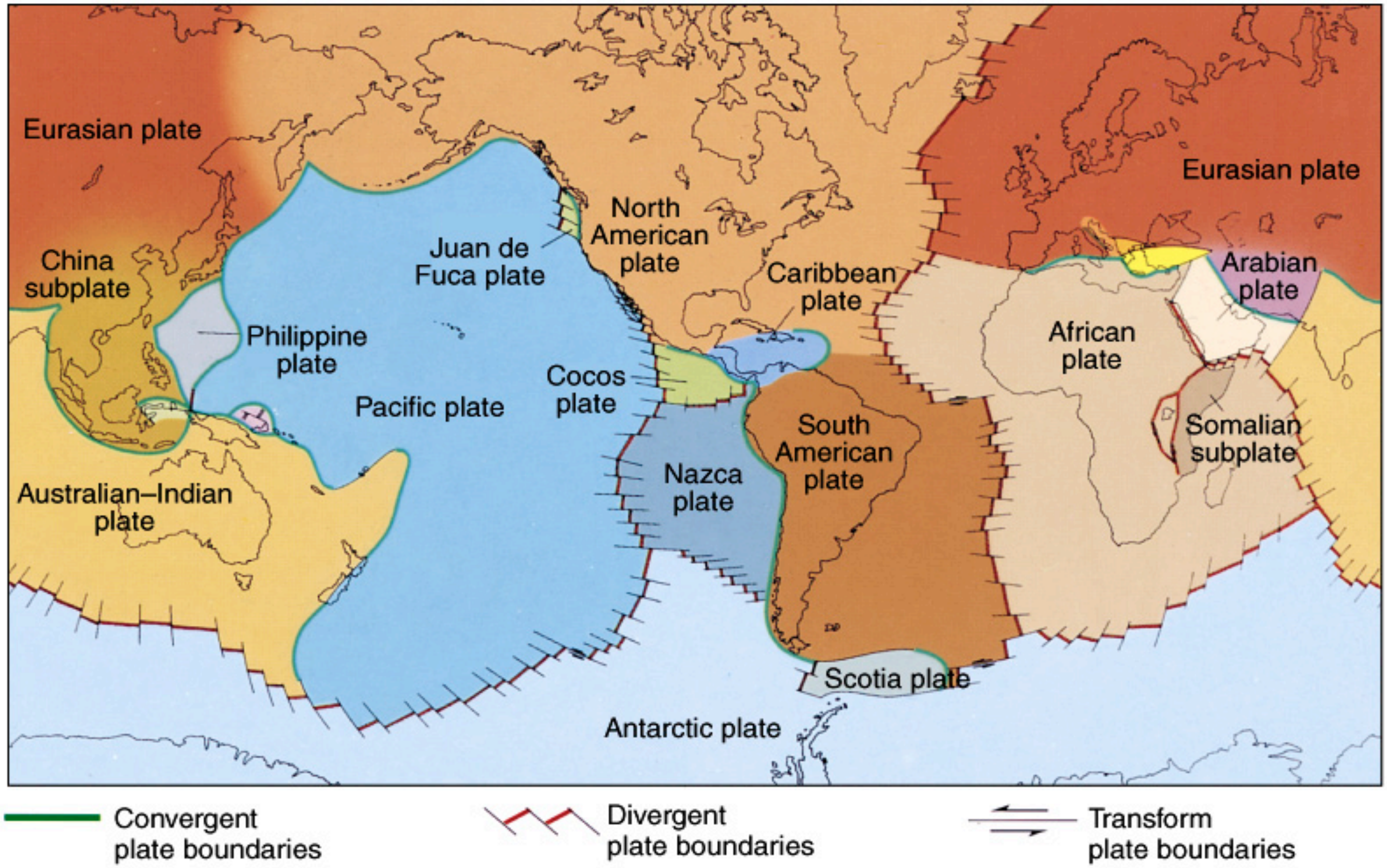
Fig. 17.11. Age of the sea floor

Geology of the Ocean Floor

- Seafloor sediments (from Deep Sea Drilling Project) support plate tectonic theory
  - Youngest sediments resting directly on basalt near the ridge
  - Sediment just above the basalt gets older moving away from the ridge

PLATE GEOGRAPHY

- Lithosphere is divided into individual plates
  - Geologic boundaries based on structural features, not land and ocean (geographic boundaries)
  - 7 major plates: 1 entirely oceanic, others both continental & oceanic crust
  - Plates are outlined by ridges, trenches and young mountain belts



Seven major tectonic plates outlined by oceanic ridges, trenches, or young mt. ranges

Divergent Plate Margins

- Oceanic-Oceanic Crust
  - Mid-oceanic ridge with central rift valley
  - Shallow earthquakes, less than 100km
  - Basaltic lavas
  - Example: Mid-Atlantic Ridge

Divergent Plate Margins

- Continental-Continental Crust
  - Rift Valley
  - Shallow earthquakes, less than 100km
  - Basaltic and Rhyolitic volcanism
    - New material rising from the mantle produces basaltic lavas
    - Thinning continental crust melts to produce rhyolitic lavas & instrusions
    - East African Rift Valley

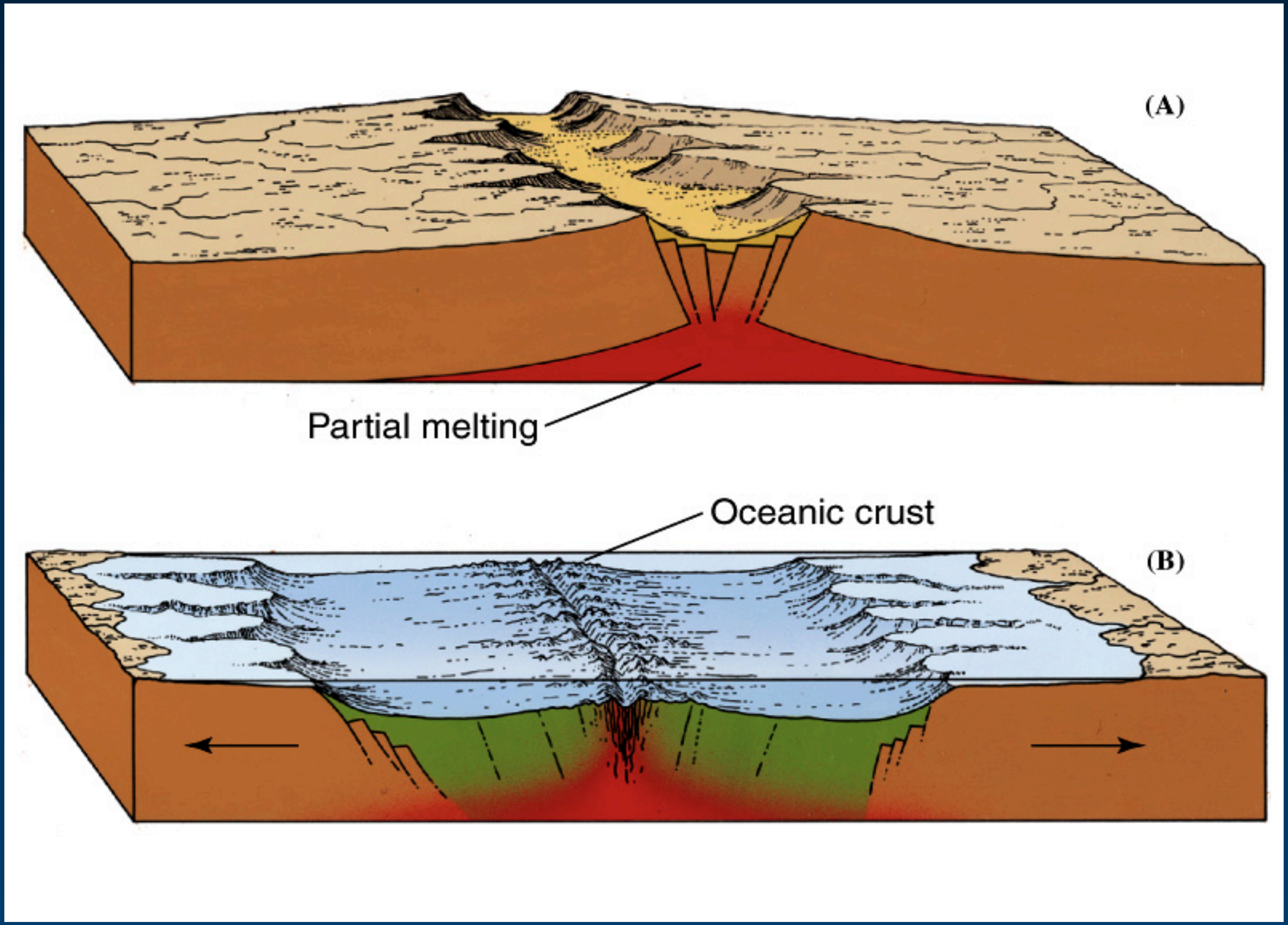


Fig. 17.15. Divergent plate margins; most active volcanic areas; quiet, unspectacular fissure eruptions.

Convergent Plate Margins

- Oceanic-Oceanic
  - Seafloor Trench
  - Shallow and deep earthquakes, 0-700 km deep
  - Andesitic volcanoes in an island arc
  - Ex.: Japan

Convergent Plate Margins

- Oceanic-Continental
  - Subduction Zone
  - Shallow and deep earthquakes, 0-700 km deep
  - Andesitic volcanoes in a continental arc
  - Ex.: Cascade range

Convergent Plate Margins

- Continental-Continental
  - Intensely folded and thrust faulted mountain belts; subduction stops; neither plate subducts into mantle
  - Both continental masses are compressed & fused into one single continental block
  - Metamorphic rks dominate; ign common too
  - Ex.: Himalayans (India & Asia colliding)

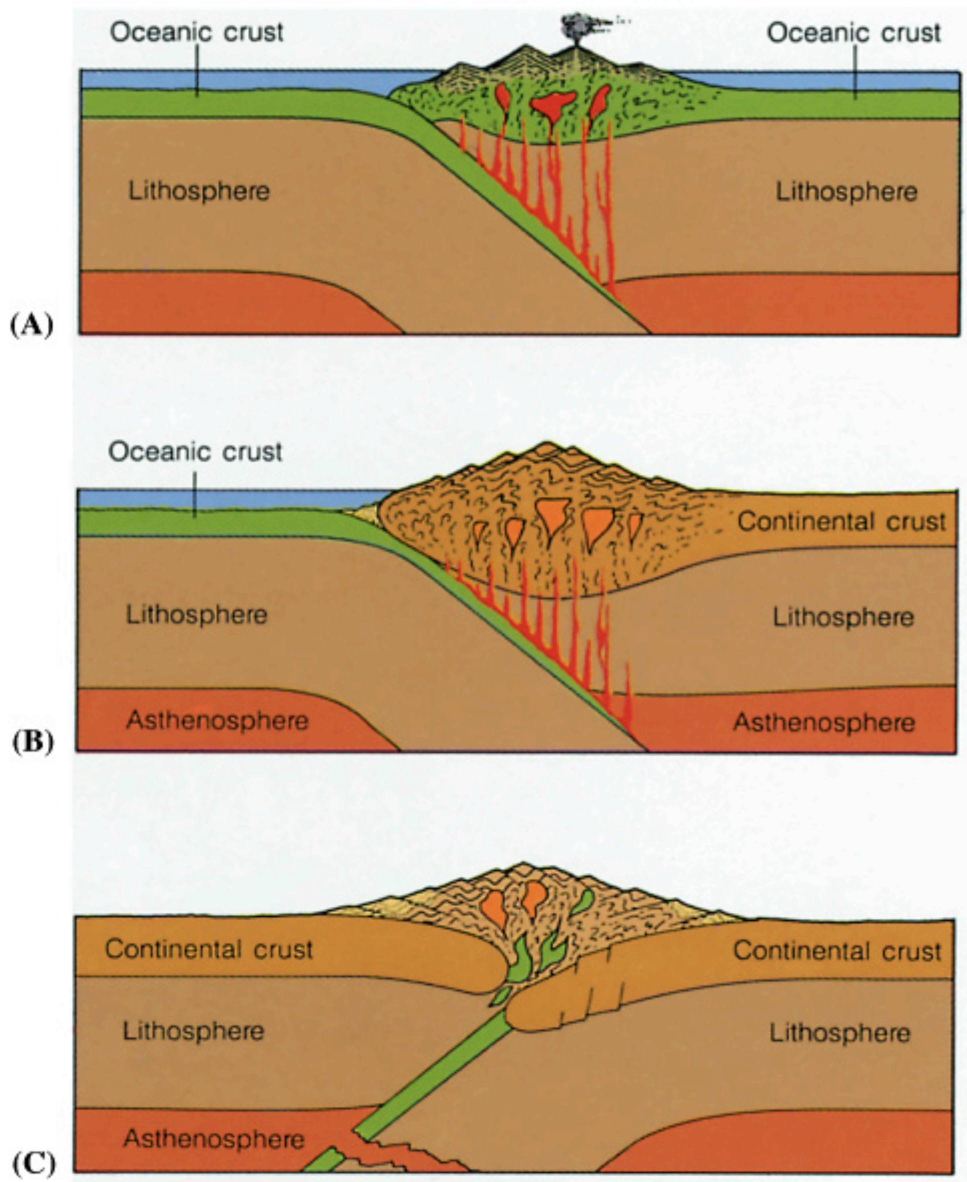


Fig. 17.16. Convergent plate boundaries; many are explosive and form steep-sided composite volcanoes

Transform Fault Margins

- Transform faults are large vertical fractures or faults in the crust
  - Movement along faults is horizontal (shearing); may extend v. long distances
  - Shallow earthquakes; No volcanic activity
  - No creating/destroying lithosphere
  - Transform faults may extend onto continents
  - Ex.: San Andreas fault

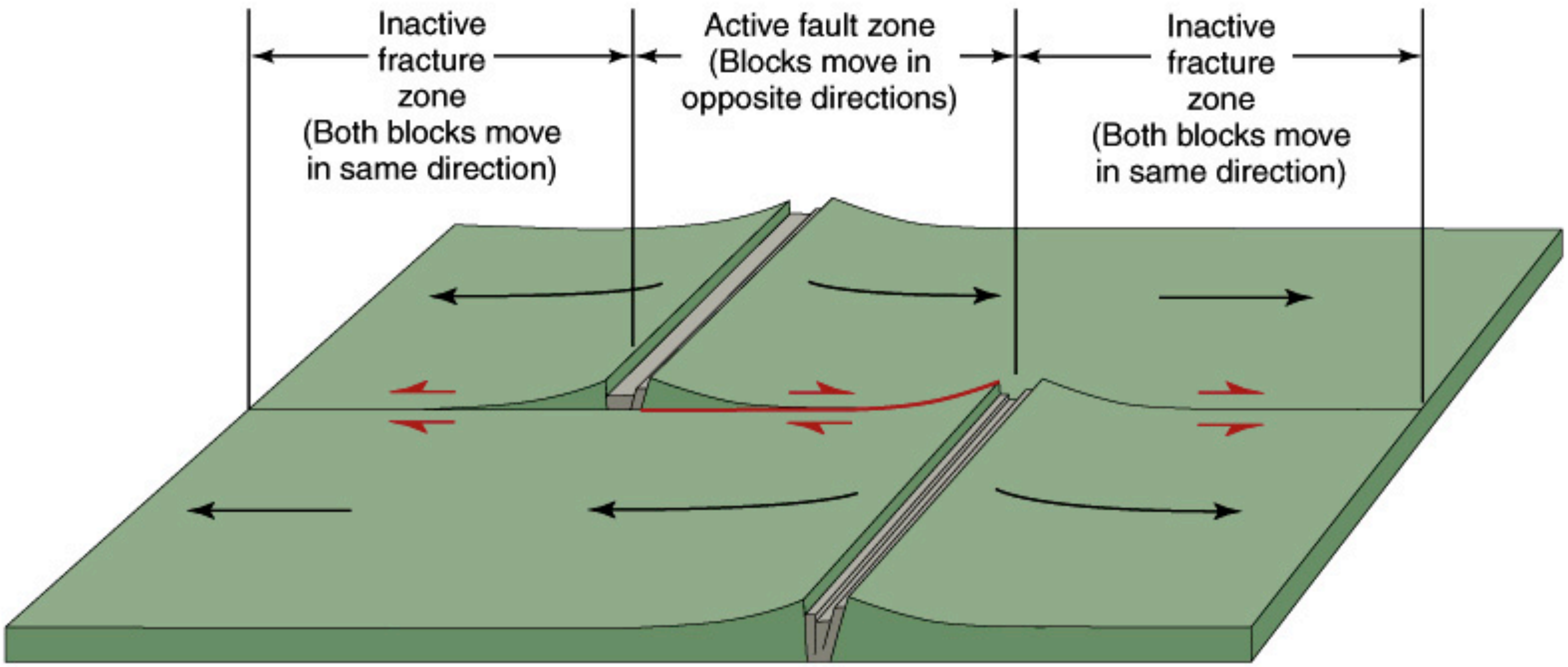


Fig. 17.18. Transform faults

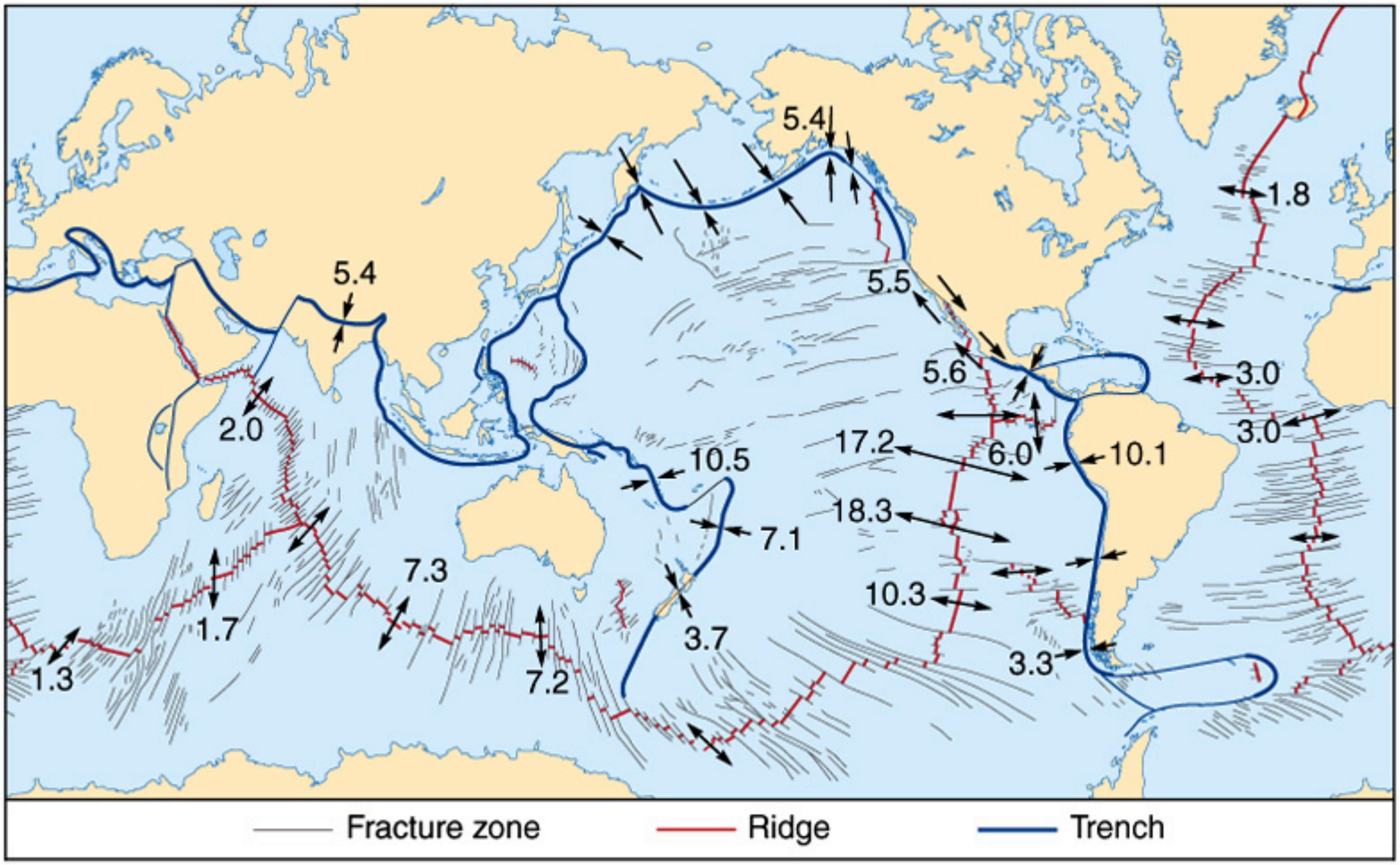


Fig. 17.20. Rates of plate motion around the world, 1 – 20 cm/yr.

End of Chapter 17

Evidence for Continental Drift

- Paleoclimate
  - Evidence of extreme changes in climate as compared to the present
    - Coal deposits in Antarctica
    - Evidence from evaporite deposits, eolian deposits & coral reefs
    - Paleoclimate reconstruction shows strange patterns unless continents are moved

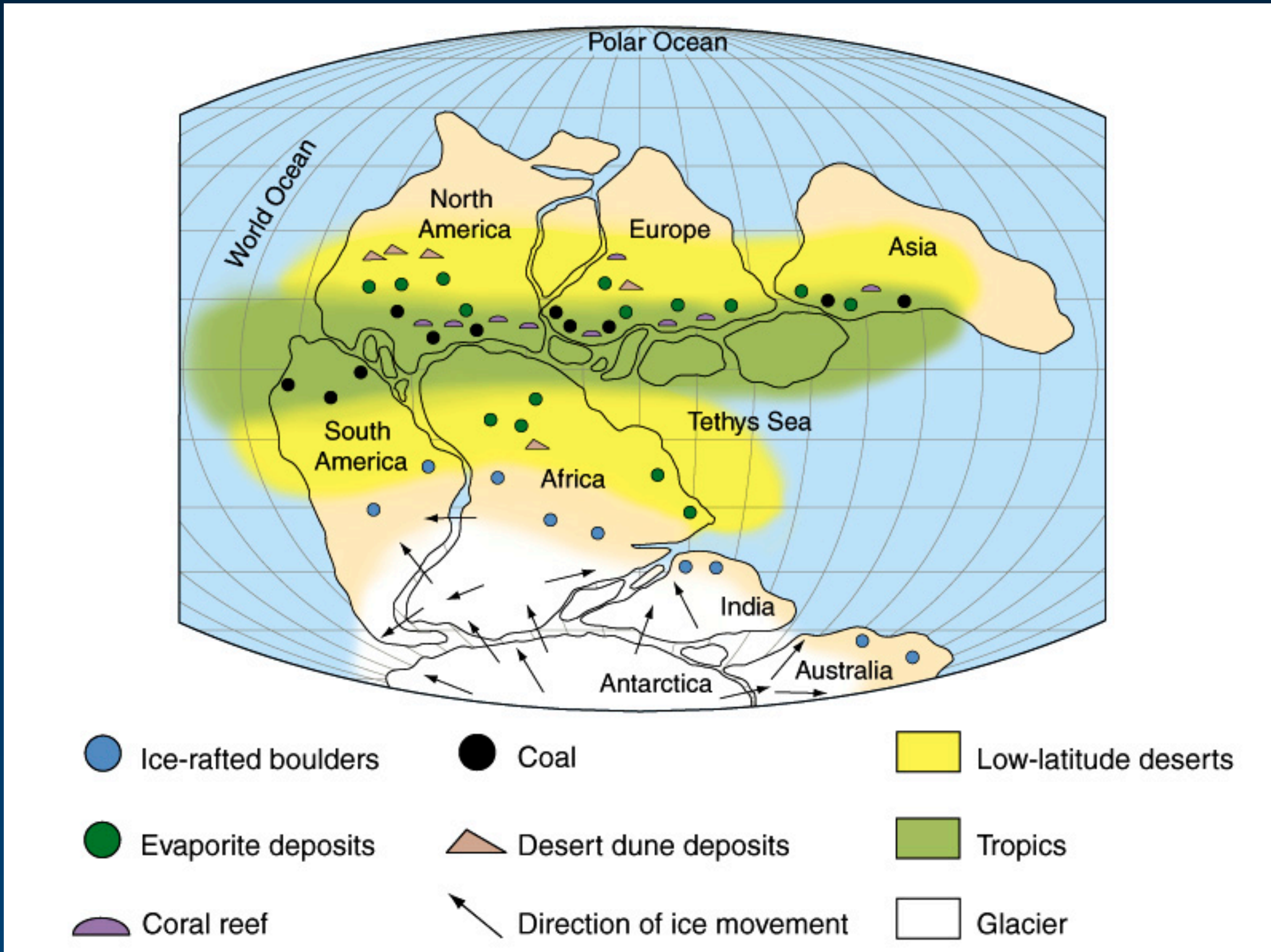


Fig. 17.6. Paleoclimate evidence

Evidence for Continental Drift

- Paleontological
  - Similarity of fossils on opposite sides of the Atlantic Ocean
    - Plants and land dwelling animals
    - No mechanism to transport across ocean
    - *Glossopteris* (fern-like plant)on all southern continents

Evidence for Continental Drift

- Rock type & structures
  - Distinct rock type and deformation on both sides of the Atlantic Ocean
    - Cape of Good Hope (S. Afr)fold belt and equivalent – S.Africa & Argentina
    - Appalachian Mtns and equivalent – U.S., Canada, Scotland & Norway
    - Only occur in rocks older than Cretaceous Period (> 145 mya)

Evidence for Continental Drift

- Glaciation
  - Late Paleozoic glaciation
    - Covered large portions of the southern continents
    - Distinct glacial deposit
    - Glacial striations indicate direction of movement
    - No evidence for glaciation on northern continents at this time